AD 256 633

OTS PB 171627

May 18, 1961
DMIC Memorandum 108

REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF TUNGSTEN

DEFENSE METALS INFORMATION CENTER
BATTELLE MEMORIAL INSTITUTE
COLUMBUS 1, OHIO

REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF TUNGSTEN

V. D. Barth*

This memorandum briefly reviews major recent developments in the technology of tungsten. With a few exceptions, the period covered is from January through April, 1961.

FABRICATION

The explosive compaction of tungsten powders has been carried out at Battelle.[1]** It is possible at ambient temperatures to explosively compact tungsten powders to 95 per cent of full density. Explosive forming of tungsten nozzles using rolled and welded sheet tubes in an aluminum bath at 1800 F is of current interest for making asymmetrical nozzle shapes. As in the case of tungsten sheet for spin-type operations (spin forming, shear spinning), there is some question regarding the best source of sheet for this purpose.

Recently a tungsten nozzle shape weighing 42 pounds has been skull melt - vacuum cast in graphite.[2] Carbon contamination ranged from none to 0.010 inch in depth. Cleanup was possible by machining about 0.125 inch from the OD of the casting. Surface imperfections were believed to be related to impurities in the graphite mold, and it is thought that these impurities would have to be present in amounts less than 10 ppm to avoid gas-pocket formation.

Continued work on the tungsten-forging development program at Thompson-Ramo-Wooldridge[3] indicates that successful forging is largely dependent on prior effective deoxidation practice. A process has been developed for producing forging billets of 85W-15Mo alloy. The method involves arc-melting deoxidized 85W-15Mo ingots, and extruding above 3000 F to 1- to 1-1/2-inch diameter bars. The extrusion of W-0.88Cb, W-7.0Mo, and W-0.1Zr is being considered.

Tungsten sheet-rolling programs are being pursued at both Fansteel and Universal-Cyclops, but no data are available as yet for publication.

The welding of tungsten has been of considerable recent interest. Results of extensive work on this topic[4] have indicated that electron-beam butt-welded joints are as strong as roll-formed tungsten above 3000 F (at temperatures where recrystallization occurs in the adjacent sheet). Between 1500 F and 3000 F, the welds are significantly weaker because of the strength difference between the coarse-grained cast weld structure, the related recrystallized heat-affected zones, and the stronger wrought structure of the adjacent sheet. The feasibility of butt welding the girth seam between two conical tungsten nozzle components was established. It is concluded that improvements in the quality of tungsten through higher purity or alloying are necessary to yield weld-zone properties for use in applications where the low

---

* Principal Metallurgist, Powder Metallurgy Division, Battelle Memorial Institute.

** References are listed at the end of this memorandum.

ductility of present welds cannot be tolerated. Somewhat more optimistic results have been reported on the basis of work at Aerojet's Downey facility. Fusion welds in tungsten sheet are reported to have been remarkably successful, with a sharp-bend transition of 1100 F for the weld metal and 700 F for the adjacent sheet. Relatively fine grain size is achieved by increasing the speed of weld travel.

Brazing of tungsten to graphite is being tried with a variety of brazing alloys, including a Mo-30Cr-20Ni alloy, a W-50Ni alloy, Nicrobraze, GE J-8100, and Coast Metal 62.

Plasma-jet coating of graphite is being carried out in a number of places. The Plasmakote Corporation is engaged in making composite coatings, one component of which is tungsten.(5) The buildup of free-standing forms by this process is also being tried. The sintering of tungsten deposited with a plasma-jet spray gun in which nickel or some other additive accelerates the consolidation rate is under investigation elsewhere.(6)

PROPERTIES

The determination of mechanical properties of tungsten and tungsten-base alloys at elevated temperatures remains a problem. Table 1 summarizes data obtained by Kattus and Wilhelm.(7) The data were obtained on self-resistance-heated, arc-cast tensile bars.

TABLE 1. AVERAGE TENSILE PROPERTIES OF 85W-15Mo ALLOY AT DIFFERENT TEMPERATURES, HOLDING TIMES, AND STRAIN RATES

Specimens heated to test temperature within 20 seconds.

Test Temp., F	Time at Temp., Prior to Loading, sec	0.2% Offset Yield Strength, kips	Ultimate Tensile Strength, kips	Elongation in 2 in., %	Loading Time to Fracture, sec
75	--	--	41.1	0	13.8
1000	10	21.1	31.0	0.8	15.8
2000	10	18.2	29.6	13.8	20.5
3000	10	21.5	24.7	16.8	22.0
4000	10	4.7	7.05	20.5	22.8
1000	30	23.6	25.9	0.5	0.7
2000	30	18.5	32.8	16.0	1.0
3000	30	25.3	32.6	18.5	1.1
4000	30	12.1	14.7	22.0	1.3

In an investigation of the effect of surface condition on the ductile-to-brittle transition temperature of tungsten, it has been noted that the type of defect rather than the average degree of roughness is the principal factor in raising the transition temperature.(8)

STRUCTURES AND APPLICATIONS

The problem of thermal-shock resistance in deposited tungsten coatings on graphite has been approached by brazing a spun, thin-wall tungsten nozzle liner to a graphite backing. Results of tests are promising.

At the moment, forged throat inserts are in a more advanced state of development than their spun counterparts. A buckling problem has been associated with spun inserts on the Minuteman first stage. For smaller nozzles, tungsten inserts show a definite advantage over graphite nozzles, the latter being marginal at about 5500 F. For large-diameter nozzles, where the same amount of erosion results in only a small percentage of change in throat opening area, tungsten may not maintain this advantage. Until very recently at least, plasma-sprayed tungsten has been fired successfully at 6200 F only in low-pressure systems.

Porous tungsten (75-35 per cent of full density) infiltrated with copper, Al_2O_3, or some other material, may provide a possible transpiration-cooled composite. The development of tungsten-base composites capable of operating at gas temperatures above the melting point of tungsten has been reviewed in a paper by Maloof.(9) The oxidation resistance of the infiltrated structure may be better than that for tungsten alone.

REFERENCES

(1) Porembka, S. W., and Simons, C. C., "Compacting Metal Powders with Explosives", ASTME Technical Paper SP60-102 presented at the 1960-1961 Creative Manufacturing Seminars.

(2) LaMarche, A. E., Westinghouse Electric Corporation, preliminary information under a Navy contract.

(3) Nemy, A., and Grove, A. H., Thompson-Ramo-Wooldridge, preliminary information under an Air Force contract.

(4) Kearns, W. H., "Electron Beam Welding of Tungsten", General Electric Company, Final Report on Contract NOrd 18119 (December 31, 1960).

(5) Plasmakote Corporation, preliminary information under an Air Force contract.

(6) Wulff, J., Massachusetts Institute of Technology, preliminary information under a Navy contract.

(7) Kattus, J. R., and Wilhelm, C. C., "The Flexure and Tensile Properties of 85W-15Mo Alloy", December 1960, Report from Southern Research Institute to The Martin Company, Orlando.

(8) Stephens, J. R., "Effect of Surface Condition on Ductile-to-Brittle Transition Temperature of Tungsten", NASA Technical Note D-676 (February, 1961).

(9) Maloof, S. R., "Development of Ultra-High Temperature Tungsten-Base Composites for Rocket Nozzle Applications", Paper No. 1573-60 presented at the American Rocket Society, 15th Annual Meeting (December, 1960).

LIST OF DMIC MEMORANDA ISSUED (CONTINUED)
DEFENSE METALS INFORMATION CENTER
Battelle Memorial Institute
Columbus 1, Ohio

Copies of the technical memoranda listed below may be obtained from DMIC at no cost by Government agencies and by Government contractors, subcontractors, and their suppliers. Others may obtain copies from the Office of Technical Services, Department of Commerce, Washington 25, D. C. (See PB numbers and prices in parentheses).

A list of DMIC Memoranda 1-61 may be obtained from DMIC, or see previously issued memoranda.

DMIC Memorandum Number	Title
62	Effects of Rate of Heating to Aging Temperature on Tensile Properties of Ti-2.5Al-16V Alloys, August 18, 1960, (PB 161212 $0.50)
63	Notes on Large-Size Electrical Furnaces for Heat Treating Metal Assemblies, August 25, 1960
64	Recent Developments in Superalloys, September 8, 1960, (PB 161214 $0.50)
65	Compatibility of Rocket Propellants with Materials of Construction, September 15, 1960, (PB 161215 $0.50)
66	Physical and Mechanical Properties of the Cobalt-Chromium-Tungsten Alloy WI-52, September 22, 1960, (PB 161216 $0.50)
67	Development of Refractory Metal Sheet in the United States, September 20, 1960, (PB 161217 $0.50)
68	Some Physical Properties of Martensitic Stainless Steels, September 28, 1960, (PB 161218 $0.50)
69	Welding of Columbium and Columbium Alloys, October 24, 1960, (PB 161219 $0.50)
70	High Velocity Metalworking Processes Based on the Sudden Release of Electrical Energy, October 27, 1960, (PB 161220 $0.50)
71	Explosive Metalworking, November 3, 1960, (PB 161221 $0.50)
72	Emissivity and Emittance--What are They?, [illegible], 1960, (PB 161222 $0.50)
73	Current Nickel-Base High-Temperature Alloys, November 17, 1960, (PB 161223 $0.50)
74	Joining of Tungsten, November 24, 1960, (PB 161224 $0.50)
75	Review of Some Unconventional Methods of Machining, November 29, 1960
76	Production and Availability of Some High-Purity Metals, December 2, 1960
77	Rocket Nozzle Testing and Evaluation, December 7, 1960
78	Methods of Measuring Emittance, December 27, 1960
79	Preliminary Design Information on Recrystallized Mo-0.5Ti Alloy for Aircraft and Missiles, January 16, 1961
80	Physical and Mechanical Properties of Some High Strength Fine Wires, January 20, 1961
81	Design Properties as Affected by Cryogenic Temperatures (Ti-6Al-4V, AISI 4340, and 7079-T6 Alloys), January 24, 1961
82	Review of Developments in Iron-Aluminum-Base Alloys, January 30, 1961
83	Refractory Metals in Europe, February 1, 1961
84	The Evolution of Nickel-Base Precipitation-Hardening Superalloys, February 6, 1961
85	Pickling and Descaling of High-Strength, High-Temperature Metals and Alloys, February 8, 1961
86	Superalloy Forgings, February 10, 1961
87	A Statistical Summary of Mechanical-Property Data for Titanium Alloys, February 14, 1961
88	Zinc Coatings for Protection of Columbium from Oxidation at Elevated Temperatures, March 3, 1961

LIST OF DMIC MEMORANDA ISSUED
(Continued)

DMIC Memorandum Number	Title
89	Summary of Present Information on Impact Sensitivity of Titanium When Exposed to Various Oxidizers, March 5, 1961
90	A Review of the Effects of Starting Material on the Processing and Properties of Tungsten, Molybdenum, Columbium, and Tantalum, March 13, 1961
91	The Emittance of Titanium and Titanium Alloys, March 17, 1961
92	Stress-Rupture Strengths of Selected Alloys, March 23, 1961
93	A Review of Recent Developments in Titanium and Titanium Alloy Technology, March 27, 1961
94	Review of Recent Developments in the Evaluation of Special Metal Properties, March 28, 1961
95	Strengthening Mechanisms in Nickel-Base High-Temperature Alloys, April 4, 1961
96	Review of Recent Developments in the Technology of Molybdenum and Molybdenum-Base Alloys, April 7, 1961
97	Review of Recent Developments in the Technology of Columbium and Tantalum, April 10, 1961
98	Electropolishing and Chemical Polishing of High-Strength, High-Temperature Metals and Alloys, April 12, 1961
99	Review of Recent Developments in the Technology of High-Strength Stainless Steels, April 14, 1961
100	Review of Current Developments in the Metallurgy of High-Strength Steels, April 20, 1961
101	Statistical Analysis of Tensile Properties of Heat-Treated Mo-0.5Ti Sheet, April 24, 1961
102	Review of Recent Developments on Oxidation-Resistant Coatings for Refractory Metals, April 26, 1961
103	The Emittance of Coated Materials Suitable for Elevated-Temperature Use, May 4, 1961
104	Review of Recent Developments in the Technology of Nickel-Base and Cobalt-Base Alloys, May 5, 1961
105	Review of Recent Developments in the Metallurgy of Beryllium, May 10, 1961
106	Survey of Materials for High-Temperature Bearing and [illegible] Applications, May 12, 1961
107	A Comparison of the Brittle Behavior of Metallic and Nonmetallic Materials, May 16, 1961